In re Patent Application of:
KANE ET AL
Serial No. **10/662,086**
Filed: **09/12/03**

IN THE CLAIMS

1. (Original) A laser apparatus comprising:

a Neodymium-doped lasing material, wherein the lasing material includes a first-surface that is substantially transparent to a pump radiation and substantially reflective to laser radiation generated by an interaction between the pump radiation and the Neodymium-doped lasing material, wherein the laser radiation is characterized by a vacuum wavelength corresponding to an atomic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level of Neodymium in the lasing material, the lasing material further having a second surface that transmits at least a portion of the laser radiation; and

a passive Q-switch optically coupled to the second surface of the lasing material;

wherein lasing material and Q-switch are configured to produce pulses of the laser radiation;
wherein the pulses are characterized by a pulse length of greater than zero and less than about 1.5 nanoseconds and a pulse repetition rate greater than about 100 kHz.

2. (Original) The apparatus of claim 1 wherein the lasing material is Nd:YVO_4, Nd:$GdVO_4$, Nd:YLF or Nd:YAG.

3. (Currently Amended) The apparatus of claim ~~1~~ 2 wherein the lasing material is Nd:YVO_4.

4. (Original) The apparatus of claim 3, wherein the Neodymium concentration in the lasing material is greater than about 1% and less than about 3%.

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5. (Original) The apparatus of claim 4 wherein the Neodymium concentration in the lasing material is about 2%.

6. (Original) The apparatus of claim 3 wherein the lasing material is between about 50 microns thick and about 100 microns thick.

7. (Original) The apparatus of claim 3 wherein the first surface of the lasing material is configured to transmit between about 0.5% and about 2% of the laser radiation incident upon it from within the lasing material.

8. (Original) The apparatus of claim 7 wherein the first surface of the lasing material is configured to transmit about 1% of the laser radiation incident upon it from within the lasing material.

9. (Original) The apparatus of claim 8 wherein the first surface is configured to transmit about 0.94% of laser radiation of the ordinary polarization and about 0.98% of laser radiation of the extraordinary polarization.

10. (Original) The apparatus of claim 1 wherein the Q-switch includes a saturable Bragg reflector (SBR).

11. (Original) The apparatus of claim 10 wherein the SBR includes a substrate, semiconductor mirror stack having alternating high and low refractive index layers, a quantum well stack having between about 3 and about 15 quantum wells, and a dielectric overcoat,
wherein the semiconductor mirror stack is disposed between the substrate and the quantum wells, and
wherein the quantum well stack is disposed between the semiconductor mirror stack and the dielectric overcoat.

12. (Original) The apparatus of claim 11 further comprising a buffer layer disposed between the substrate and the semiconductor mirror stack.

13. (Original) The apparatus of claim 11 wherein the alternating high and low refractive index layers are greater than 99.5% reflecting at the wavelength of the laser radiation from the Neodymium-doped lasing material.

14. (Original) The apparatus of claim 13 wherein the alternating high and low refractive index layers include alternating layers of $Al_xGa_{1-x}As$ and $Al_yGa_{1-y}As$, where x is between 0 and about 0.1 and y is between about 0.9 and 1.

15. (Original) The apparatus of claim 14 wherein the optical thickness of the quantum well stack is an odd multiple of one-quarter wavelength ($\lambda/4$) of the laser radiation from the Neodymium-doped lasing material.

16. (Original) The apparatus of claim 15 wherein the thickness of each layer of $Al_xGa_{1-x}As$ and each layer of $Al_yGa_{1-y}As$ has an optical thickness of ¼ wave at the wavelength of the laser radiation from the Neodymium-doped lasing material.

17. (Original) The apparatus of claim 11 wherein the quantum well stack includes alternating layers of GaAsP and InGaAs.

18. (Original) The apparatus of claim 17 wherein the thickness of the InGaAs layers is chosen to create photoluminescence at 930 nm ± 15 nm, and the thickness of the GaAsP is chosen to balance the strain created by the InGaAs.

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19. (Original) The apparatus of claim 17 wherein the quantum well stack includes between nine and twelve quantum wells.

20. (Original) The apparatus of claim 17 wherein the quantum well stack includes one or more spacer layers of GaAs or InGaP that place the optical thickness of the quantum well stack at an odd number of one-quarter wavelengths of the laser radiation from the Neodymium-doped lasing material.

21. (Original) The apparatus of claim 11 wherein the dielectric overcoat includes alternating layers of SiO_2 and HfO_2.

22. (Currently Amended) ~~The apparatus of claim 21~~ A laser apparatus comprising:

a Neodymium-doped lasing material, wherein the lasing material includes a first-surface that is substantially transparent to a pump radiation and substantially reflective to laser radiation generated by an interaction between the pump radiation and the Neodymium-doped lasing material, wherein the laser radiation is characterized by a vacuum wavelength corresponding to an atomic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level of Neodymium in the lasing material, the lasing material further having a second surface that transmits at least a portion of the laser radiation; and

a passive Q-switch optically coupled to the second surface of the lasing material; and

wherein the lasing material and the Q-switch are configured to produce pulses of the laser radiation;

wherein the pulses are characterized by a pulse length of greater than zero and less than about 1.5 nanoseconds and a pulse repetition rate greater than about 100 kHz;

wherein the Q-switch includes a saturable Bragg reflector (SBR);

wherein the SBR includes a substrate, semiconductor mirror stack having alternating high and low refractive index layers, a quantum well stack having between about 3 and about 15 quantum wells, and a dielectric overcoat;
wherein the semiconductor mirror stack is disposed between the substrate and the quantum wells;
wherein the quantum well stack is disposed between the semiconductor mirror stack and the dielectric overcoat;
wherein the dielectric overcoat includes alternating layers of SiO_2 and HfO_2; and
wherein the dielectric overcoat has a reflectivity of between about 87% and about 96% at the wavelength of the laser radiation from the Neodymium-doped lasing material.

23. (Original) The apparatus of claim 22 wherein the dielectric overcoat has a reflectivity of greater than about 90% at the wavelength of the pump radiation.

24. (Currently Amended) The apparatus of claim 3 wherein the pump radiation is supplied by a source of pump radiation ~~is~~ capable of providing greater than about 400 watts/mm^2 of pump radiation to the lasing material.

25. (Original) A passively Q-switched laser (PQSL), comprising:
a source of pump radiation;
a Neodymium-doped lasing material, wherein the lasing material includes a first-surface that is substantially transparent to the pump radiation and substantially reflective to laser radiation characterized by an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level of Neodymium in the lasing material, the lasing

material further having a second surface that transmits at least a portion of the laser radiation; and

a passive Q-switch optically coupled to the second surface of the lasing material;

wherein the source of pump radiation, lasing material and Q-switch are configured to produce pulses of laser radiation characterized by a wavelength corresponding to an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level;

wherein the pulses are characterized by a pulse length of greater than zero and less than about 1.5 nanoseconds and a pulse repetition rate greater than about 100 kHz.

26. (Original) The PQSL of claim 25 wherein the source of pump radiation is a laser diode.

27. (Original) The PQSL of claim 26, further comprising a first, second and third lens,

wherein the first lens reduces the divergence of the pump radiation from the laser diode along a fast axis,

wherein the second lens collimates the pump radiation from the first lens, and

wherein the third lens focuses the pump radiation from the second lens into the Neodymium-doped lasing material and collimates laser radiation from the Neodymium-doped lasing material.

28. (Original) The PQSL of claim 27 wherein the laser diode, first, second, and third, lenses are configured to provide an intensity of greater than about 400 Watts/mm^2 of the pump radiation in the Neodymium-doped lasing material.

29. (Original) The PQSL of claim 27, further comprising a beamsplitter disposed between the second and third lenses, wherein the beamsplitter is configured to transmit pump radiation

from the laser diode and reflect laser radiation from the Neodymium-doped lasing material.

30. (Original) The PQSL of claim 25 wherein the lasing material is $Nd:YVO_4$, $Nd:GdVO_4$, Nd:YLF or Nd:YAG.

31. (Original) The PQSL of claim 30 wherein the lasing material is $Nd:YVO_4$.

32. (Original) The PQSL of claim 31, wherein the Neodymium concentration in the lasing material is greater than about 1% and less than about 3%.

33. (Original) The PQSL of claim 32 wherein the Neodymium concentration in the lasing material is about 2%.

34. (Original) The PQSL of claim 31 wherein the lasing material is between about 50 microns thick and about 100 microns thick.

35. (Original) The PQSL of claim 31 wherein the first surface of the lasing material is configured to transmit between about 0.5% and about 2% of the laser radiation incident upon it from within the lasing material.

36. (Original) The PQSL of claim 35 wherein the first surface of the lasing material is configured to transmit about 1% of the laser radiation incident upon it from within the lasing material.

37. (Original) The PQSL of claim 36 wherein the first surface is configured to transmit about 0.94% of laser radiation of the ordinary polarization and about 0.98% of laser radiation of the extraordinary polarization.

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38. (Original) The PQSL of claim 25 wherein the Q-switch includes a saturable Bragg reflector (SBR).

39. (Original) The PQSL of claim 38 wherein the SBR includes a substrate, a semiconductor mirror stack having alternating high and low refractive index layers, a quantum well stack having between about 3 and about 15 quantum wells, and a dielectric overcoat,
wherein the semiconductor mirror stack is disposed between the substrate and the quantum well stack, and
wherein the quantum well stack is disposed between the semiconductor mirror stack and the dielectric overcoat.

40. (Original) An apparatus for producing blue light comprising:
a neodymium-doped cladding-pumped fiber device for amplifying laser radiation;
an optical harmonic generator optically coupled to the fiber device for increasing a frequency of the laser radiation to produce a blue output radiation; and
a passively Q-switched laser (PQSL) optically coupled to the neodymium-doped cladding-pumped fiber device, wherein the PQSL is configured to produce the laser radiation, the laser radiation having a harmonic that is blue, whereby the harmonic generator interacts with the laser radiation to produce blue light,
wherein the PQSL includes:
a source of pump radiation;
a Neodymium-doped lasing material, wherein the lasing material includes a first-surface that is substantially transparent to the pump radiation and substantially reflective to laser radiation characterized by a by an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level of Neodymium in the lasing material, the lasing material further having a second surface that transmits at least a portion of the laser radiation; and

a passive Q-switch optically coupled to the second surface of the lasing material;
wherein the source of pump radiation, lasing material and Q-switch are configured to produce pulses of the laser radiation characterized by a wavelength corresponding to an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level;
wherein the pulses are characterized by a pulse length of greater than zero and less than about 1.5 nanoseconds and a pulse repetition rate greater than about 100 kHz.

41. (Original) The apparatus of claim 40 wherein the lasing material is Nd:YVO_4, Nd:$GdVO_4$, Nd:YLF or Nd:YAG.

42. (Original) The apparatus of claim 41 wherein the lasing material is Nd:YVO_4.

43. (Original) The apparatus of claim 42, wherein the Neodymium concentration in the lasing material is greater than about 1% and less than about 3%.

44. (Original) The apparatus of claim 43 wherein the Neodymium concentration in the lasing material is about 2%.

45. (Original) The apparatus of claim 42 wherein the lasing material is between about 50 microns thick and about 100 microns thick.

46. (Original) The apparatus of claim 42 wherein the first surface of the lasing material is configured to transmit between about 0.5% and about 2% of the laser radiation incident upon it from within the lasing material.

47. (Original) The apparatus of claim 46 wherein the first surface of the lasing material is configured to transmit about 1%

of the laser radiation incident upon it from within the lasing material.

48. (Original) The apparatus of claim 47 wherein the first surface is configured to transmit about 0.94% of laser radiation of the ordinary polarization and about 0.98% of laser radiation of the extraordinary polarization.

49. (Original) The apparatus of claim 40 wherein the Q-switch includes a saturable Bragg reflector (SBR).

50. (Original) The apparatus of claim 49 wherein the SBR includes a substrate, a semiconductor mirror stack having alternating high and low refractive index layers, a quantum well stack having between about 3 and about 15 quantum wells, and a dielectric overcoat,
wherein the semiconductor mirror stack is disposed between the substrate and the quantum well stack, and
wherein the quantum well stack is disposed between the semiconductor mirror stack and the dielectric overcoat.

51. (Original) The apparatus of claim 40 wherein the source of pump radiation is a laser diode.

52. (Original) The apparatus of claim 51, further comprising a first, second and third lens,
wherein the first lens reduces a divergence of the pump radiation from the laser diode along a fast axis,
wherein the second lens collimates the pump radiation from the first lens, and
wherein the third lens focuses the pump radiation from the second lens into the Neodymium-doped lasing material and collimates laser radiation from the Neodymium-doped lasing material.

53. (Original) The apparatus of claim 52 wherein the laser diode, first, second, and third, lenses are configured to provide an intensity of greater than about 400 Watts/mm^2 of the pump radiation in the Neodymium-doped lasing material.

54. (Original) The apparatus of claim 52, further comprising a beamsplitter disposed between the second and third lenses, wherein the beamsplitter is configured to transmit pump radiation from the laser diode and reflect laser radiation from the Neodymium-doped lasing material.

55. (Currently Amended) A display system, comprising:
a light source that produces two or more different colors of light including blue light;
a modulating means optically coupled to the light source for modulating an intensity of the two or more different colors of light to form a modulated output beam;
a scanning means optically coupled to the modulating means for forming an image from the modulated output beam,
wherein the light source includes[[.]]<u>:</u>
a neodymium-doped cladding-pumped fiber device for amplifying laser radiation;
an optical harmonic generator optically coupled to the fiber device for increasing a frequency of the laser radiation to produce a blue output radiation; and
a passively Q-switched laser (PQSL) optically coupled to the neodymium-doped cladding-pumped fiber device, wherein the PQSL is configured to produce the laser radiation, wherein the laser radiation has a harmonic that is blue, whereby the harmonic generator interacts with the laser radiation to produce blue light,
wherein the PQSL includes:
a source of pump radiation;

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a Neodymium-doped lasing material, wherein the lasing material includes a first-surface that is substantially transparent to the pump radiation and substantially reflective to laser radiation characterized by an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level of Neodymium in the lasing material, the lasing material further having a second surface that transmits at least a portion of the laser radiation; and

a passive Q-switch optically coupled to the second surface of the lasing material;

wherein the source of pump radiation, lasing material and Q-switch are configured to produce pulses of laser radiation characterized by a wavelength corresponding to an electronic transition from the $^4F_{3/2}$ level to the $^4I_{9/2}$ level;

wherein the pulses are characterized by a pulse length of greater than zero and less than about 1.5 nanoseconds and a pulse repetition rate greater than about 100 kHz.